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Patent
Attorney Docket No. 1015290-000457

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of	)	**Mail Stop APPEAL BRIEF - PATENTS**
Jerome S. Hubacek et al.	)	Group Art Unit: 1763
Application No.: 09/749,916	)	Examiner: LUZ L ALEJANDRO MULERO
Filing Date: December 29, 2000	)	Confirmation No.: 6834
Title: ELECTRODE FOR PLASMA PROCESSES AND METHOD FOR MANUFACTURE AND USE THEREOF	)	

AMENDMENT/REPLY TRANSMITTAL LETTER

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Enclosed is a reply for the above-identified patent application.

☐ A Petition for Extension of Time is enclosed.

☐ _______ Terminal Disclaimer(s) and the ☐ $ 65 ☐ $ 130 fee per Disclaimer due under 37 C.F.R. § 1.20(d) are enclosed.

☒ Also enclosed is/are: Reply Brief to Examiner's Answer dated June 1, 2006; One (1) Reference

☐ Small entity status is hereby claimed.

☐ Applicant(s) requests continued examination under 37 C.F.R. § 1.114 and enclose the ☐ $ 395 ☐ $ 790 fee due under 37 C.F.R. § 1.17(e).

☐ Applicant(s) requests that any previously unentered after final amendments not be entered. Continued examination is requested based on the enclosed documents identified above.

☐ Applicant(s) previously submitted _____________ on _____________ for which continued examination is requested.

☐ Applicant(s) requests suspension of action by the Office until at least _____________, which does not exceed three months from the filing of this RCE, in accordance with 37 C.F.R. § 1.103(c). The required fee under 37 C.F.R. § 1.17(i) is enclosed.

☐ A Request for Entry and Consideration of Submission under 37 C.F.R. § 1.129(a) (1809/2809) is also enclosed.

☒ No additional claim fee is required.

☐ An additional claim fee is required, and is calculated as shown below:

AMENDED CLAIMS					
	No. of Claims	**Highest No. of Claims Previously Paid For**	**Extra Claims**	**Rate**	**Additional Fee**
Total Claims	23	41	0	x $ 50 (1202)	$ 0
Independent Claims	3	3	0	x $ 200 (1201)	0
☐ If Amendment adds multiple dependent claims, add $ 360 (1203)					$ 0
Total Claim Amendment Fee					**$ 0**
☐ Small Entity Status claimed - subtract 50% of Total Claim Amendment Fee					0
TOTAL ADDITIONAL CLAIM FEE DUE FOR THIS AMENDMENT					**$ 0**

☐ Charge _______________ to Deposit Account No. 02-4800 for the fee due.

☐ A check in the amount of _______________ is enclosed for the fee due.

☐ Charge_______________ to credit card for the fee due. Form PTO-2038 is attached.

☒ The Director is hereby authorized to charge any appropriate fees under 37 C.F.R. §§ 1.16, 1.17 and 1.20(d) and 1.21 that may be required by this paper, and to credit any overpayment, to Deposit Account No. 02-4800. This paper is submitted in duplicate.

Respectfully submitted,

BUCHANAN INGERSOLL AND ROONEY PC

Date July 31, 2006

By: ______________________
Edward A. Brown
Registration No. 35033

P.O. Box 1404
Alexandria, VA 22313-1404
703 836 6620

Patent
Attorney's Docket No. 1015290-000457

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of	Mail Stop APPEAL BRIEF - PATENTS
Jerome S. Hubacek et al.	Group Art Unit: 1763
Application No.: 09/749,916	Examiner: Luz L. Alejandro Mulero
Filed: December 29, 2000	Confirmation No.: 6834
For: ELECTRODE FOR PLASMA PROCESSES AND METHOD FOR MANUFACTURE AND USE THEREOF	

REPLY BRIEF

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

This is a reply to the Examiner's Answer dated June 1, 2006.

I. The Low Resistivity Silicon Electrode Provides Unexpected Advantages

The claimed low resistivity, silicon electrode provides superior, unexpected advantages as compared to other electrodes that do not have the claimed combination of thickness **and** low resistivity. The inventors determined that making the electrode 0.25 inch and thicker unexpectedly increases the electrode lifetime and allows the electrode to be used at higher power levels without suffering cracking failure, in contrast to thinner electrodes exposed to such higher power levels.

Increasing the electrode thickness also desirably decreases the electrical resistance of the electrode from the center to the edge, but increases the electrode's electrical resistance in the thickness direction. The inventors determined that by **also** decreasing the electrical resistivity of the electrode, the electrode's resistance is desirably decreased. The low resistivity, silicon electrode provides improved

impedance to ground, which improves plasma confinement and the corresponding process window; improved plasma processing, such as increased etching rate while maintaining etch rate uniformity; and improved temperature control by minimizing heat-up and reducing ohmic losses, whereby power can be more efficiently coupled into the plasma. (Specification at page 6, lines 2-14; page 11, line 17 to page 12, line 6; and page 14, lines 1-3). Accordingly, the low resistivity electrode also provides unexpectedly improved plasma processing performance as compared to other electrodes that do not have the claimed combination of thickness **and** low resistivity.

The claimed low resistivity, silicon electrode is adapted to be mounted in a plasma reaction chamber including a **confinement ring**, which is used in semiconductor substrate processing. The recited confinement ring causes a pressure differential in the chamber and increases the electrical resistance between the chamber walls and the plasma to thereby confine plasma between the upper electrode and a lower electrode of the reaction chamber. (Substitute Appeal Brief at page 20, second paragraph). The **combination** of the claimed low resistivity silicon electrode and the confinement ring provides enhanced plasma confinement effects during plasma processing of substrates in a plasma processing chamber.

II. Evidence of the Unexpected Advantages That are Provided by the Claimed Low Resistivity Silicon Electrode Has Been Established

The Second Declaration By Jerome S. Hubacek Under 37 C.F.R. § 1.132 ("the second Hubacek Declaration") provided evidence of the unexpected superiority of the claimed subject matter as compared to the applied references. (Substitute

Appeal Brief at pages 12 to 17). This evidence established that the claimed low resistivity, silicon electrode provides:

1. Reduced center-to-edge temperature gradient;
2. Increased lifetime;
3. Reduced byproduct deposition behind the electrode;
4. Reduced electrical resistance; and
5. Increased plasma confinement.

However, the Examiner's Answer contends that the evidentiary showings with respect to the reduced center-to-edge temperature gradient and increased lifetime are merely "expected" and/or "insufficient" to show unexpected results.

The Examiner states that "one of ordinary skill in the art would recognize that the thicker an electrode is, the less cracking problems the electrode would have." (Examiner's Answer at page 20, lines 14-16). To the extent that the Examiner has taken Official Notice of this alleged general common knowledge regarding electrode cracking behavior, **none** of the references applied in the rejections actually provides any such evidence of this common knowledge. The Examiner has also cited no other evidence to support this allegation of general common knowledge. However, as set forth in M.P.E.P. § 2144.03(B):

> Ordinarily, there must be some form of evidence in the record to support an assertion of common knowledge. See *Lee*, 277 F.3d at 1344-45, 61 USPQ2d at 1434-35 (Fed. Cir. 2002); *Zurko*, 258 F.3d at 1386, 59 USPQ2d at 1697 (holding that general conclusions concerning what is 'basic knowledge' or 'common sense' to one of ordinary skill in the art without specific factual findings and some concrete evidence in the record to support these findings will not support an obviousness rejection).

Because the Examiner has made a general conclusion of common knowledge with there being **no** evidence in the record to support the assertion, the Examiner's allegation lacks substantial evidence to support it and thus is improper.

The Examiner further states:

> [T]he fact that a thicker electrode results in a decreased center to edge temperature gradient is **an expected result** rather than an unexpected result. Moreover, the importance of the specific claimed range of 0.25-0.5 inches has not been demonstrated by the data. Furthermore, appendix B **only shows three tested sample[s]** and therefore is an extremely small sample from which to draw any conclusions. (Examiner's Answer at page 21, lines 8-12; Emphasis added).

The Examiner further contends that U.S. Patent No. 5,993,596 to Uwai et al. ("Uwai") provides support for showing that thicker electrodes have a high heat capacity or smaller temperature gradient, and that Uwai was cited for the general teaching that a thicker electrode, **regardless of the material**, will have a smaller temperature gradient. (Examiner's Answer at page 21, lines 13-20).

Uwai does **not** support the Examiner's position that the reduced center-to-edge temperature gradient **and increased lifetime** provided by the claimed low resistivity, **silicon** electrode are expected results. Uwai is concerned **only** with glassy carbon electrodes. (Uwai at column 3, lines 16-17). According to Uwai, the glassy carbon electrode plate **must** have a particular thickness (i.e., greater than 4.5 mm, which is only about 0.18 inch) **and** a particular thermal conductivity (i.e., greater than 5 W/m·K at 300K) in order to achieve the desired surface temperature distribution of the electrode. (Uwai at column 4, lines 8-12). Uwai discloses that glassy carbon electrodes are subject to warping. (Uwai at column 2, lines 52-61). Uwai does **not** disclose that the glassy carbon electrodes are subject to **cracking**

during plasma processing, much less that increasing the glassy carbon electrode thickness would have any effect on such cracking.

In contrast to the low thermal conductivity of glassy carbon disclosed in Uwai, silicon has a much higher reported thermal conductivity of 148 W/m·K. See page 2 of the attached information from Environmental Chemistry.com. Uwai provides no disclosure regarding the effect of increasing the thickness of an electrode made from silicon. Also, silicon is a brittle material that is subject to cracking. Despite this brittleness, the claimed electrode can provide an enhanced lifetime at higher power levels without cracking failure. Uwai does **not** support the position that the reduced center-to-edge temperature gradient **and** increased lifetime provided by the claimed low resistivity, **silicon** electrode are expected results in light of Uwai.

Appellants also disagree with the Examiner's contention that the number of samples reported in Appendix B of the second Hubacek Declaration is an extremely small sample from which to draw **any** conclusions. The data points in the graph in Appendix B show a clear trend indicated by a linear relationship between the electrode thickness and the power level that can be applied to the electrode without cracking failure. (Substitute Appeal Brief at page 15, first paragraph). According to this linear relationship, increasing the electrode thickness advantageously increases the power level that can be applied to the electrode without resulting cracking failure. The probative value of the range of data shown in this graph can be extended to higher values of the claimed electrode thickness range because one skilled in the art could readily ascertain this trend in the exemplified data. *In re Kollman*, 201 U.S.P.Q. 193, 199 (CCPA 1979). In view of this clear trend in the data shown in Appendix B, the Examiner has failed to give proper consideration to this evidence.

The claimed electrode also provides reduced byproduct deposition behind the electrode. However, the Examiner did not comment on these unexpected results in the Examiner's Answer. (Substitute Appeal Brief at page 15, second paragraph).

None of the applied references recognizes the unexpected advantages with respect to plasma confinement that the inventors discovered can be provided by the claimed low resistivity. Regarding the evidence presented in Appendices C and D attached to the second Hubacek Declaration, the Examiner contends that this data is insufficient to show unexpected results with respect to the claimed resistivity range. However, the Examiner has provided **no** reasoning in support of this contention. The data shown in Appendices C and D demonstrate that decreasing impedance of the electrode improves confinement, which is highly desirable in semiconductor processing because by improving confinement, the confinement window and corresponding process window are increased. (Substitute Appeal Brief at page 17, lines 3-22).

Accordingly, the rejection of Claims 1, 4-10, 30, 38, 39 and 41 under 35 U.S.C. § 103(a) over Degner in view of Murai, and the rejection of Claims 3, 21, 25, 27, 31, 33-37 and 40 under 35 U.S.C. § 103(a) over Degner in view of Murai and Saito, should be reversed.

III. The Claimed Subject Matter Must be Compared to the Closest Prior Art

The Examiner states:

> The combination of the Degner et al. reference with the Murai reference discloses the claimed combination of electrode thickness and low resistivity of a silicon electrode, and therefore it is expected that the **advantages** recognized by the appellant would be present in the electrode disclosed by **the combination**

> **of the Degner et al. and the Murai references**. (Examiner's Answer at page 22, lines 9-13; Emphasis added).

This position is improper. As set forth at M.P.E.P. § 716.02(e), "an affidavit or declaration under 37 C.F.R. 1.132 must compare the claimed subject matter with the **closest prior art** to be effective to rebut a *prima facie* case of obviousness" (emphasis added, citation omitted). There is no requirement to compare the claimed subject matter with subject matter that may be suggested by a **combination of references** relied upon in a rejection under 35 U.S.C. § 103, as this "would be requiring comparison of the results of the invention and the results of the invention." *In re Chapman*, 148 USPQ 711, 714 (CCPA 1966) and MPEP § 716.02(e)(III). Thus, it is improper for the Examiner to compare the results of the claimed subject matter to subject matter that is allegedly disclosed in **the combination of Degner and Murai**, or *vice versa*. This same legal principle also applies to the other grounds of rejection advanced by the Examiner.

Assuming, for example, that Degner is the "closest prior art," then the results of the claimed subject matter should properly be compared to Degner. But Degner does not disclose the claimed low resistivity value of the silicon electrode. Accordingly, additional unexpected advantages that result from the claimed low resistivity in combination with the claimed thickness, such as increased confinement and corresponding process window, are sufficient to rebut the alleged *prima facie* obviousness.

Assuming, for example, that Murai or Sato is the "closest prior art," then the result of the claimed subject matter should properly be compared to Murai or Sato. But neither Murai or Sato discloses the claimed electrode thickness of about 0.25 inch or higher. Accordingly, additional unexpected advantages that result from the

claimed thickness in combination with the low resistivity, such as reduced center-to-edge temperature gradient, increased lifetime and reduced byproduct deposition behind the electrode, are sufficient to rebut the alleged *prima facie* obviousness. Moreover, Saito discloses a very broad resistivity range of from 0.00001-40 Ω·cm, and does not recognize the unexpected results that can be provided by the claimed low resistivity.

IV. "Inherent Obviousness" is an Improper Basis for the Rejections

The Examiner's position that "the advantages recognized by the appellant **would be present** in the electrode disclosed by the combination of the Degner et al. and the Murai references" (emphasis added) is an inherency position, and thus is an improper basis for the rejections under 35 U.S.C. § 103. As discussed above, the Examiner has cited no evidence showing that it was known to one skilled in the art at the time of the invention that the advantages provided by the claimed low resistivity, silicon electrode would necessarily result from the combination of Degner and Murai. In the absence of such evidence, in effect, the Examiner has improperly used that which only the inventors have taught against them. *In re Lee*, 61 U.S.P.Q.2d 1430, 1434.(Fed. Cir. 2002).

The Examiner's position fails to appreciate that inherency and obviousness are distinct concepts, and courts have stated that obviousness cannot be based on what is **unknown**. A result, **even if inherent**, but if **not known** at the time of the invention, **cannot** provide a proper basis for rejecting claimed subject matter as being **obvious**. *See In re Shetty*, 195 U.S.P.Q. 753, 756-57 (C.C.P.A. 1977); and *In re Spormann*, 150 U.S.P.Q. 449, 452 (C.C.P.A. 1966).

In *In re Grasselli*, 218 U.S.P.Q. 769, 776 (Fed. Cir. 1983), the Court determined that the evidence offered to support a rejection under 35 U.S.C. § 103 did not establish inherency:

> If appellant's catalyst is inherent in the Japanese patent, it has not been established by the record here and **obviousness cannot be predicated on that which is unknown**. (Emphasis added).

In *Kloster Speedsteel AB v. Crucible Inc.*, 230 U.S.P.Q. 81, 88 (Fed. Cir. 1986), the court stated:

> Stora bases a major argument on the undisputed fact that size change uniformity is an inherent property of the alloy disclosed in the '518 patent. That argument is unpersuasive when confronted by **Stora's failure to establish at trial that that inherency would have been obvious to those skilled in the art when the invention of claim 4 was made**. **Inherency and obviousness are distinct concepts.** (Emphasis added; citations omitted).

Accordingly, because the Examiner's position is an improper basis for the rejections according to the above-discussed legal precedent, the rejection of Claims 1, 4-10, 30, 38, 39 and 41 under 35 U.S.C. § 103(a) over Degner in view of Murai, and the rejection of Claims 3, 21, 25, 27, 31, 33-37 and 40 under 35 U.S.C. § 103(a) over Degner in view of Murai and Saito, should be reversed for this additional reason.

V. The Examiner Has Established No Motivation to Dope Degner's Electrode in View of Murai

Murai discloses an upper electrode 2a composed of doped silicon. See the Abstract. The electrode is doped with the same element (e.g., phosphorus) that is doped in the wafer 1 being processed in the chamber 5. The Examiner has established no motivation for making Degner's electrode from the doped material disclosed by Murai. Murai discloses that the electrode is highly doped for the

specific purpose of avoiding contamination of the wafer 1, which is doped in the chamber 5 with the same dopant. Degner does not suggest doping a wafer in a plasma processing chamber. As such, the combination of Degner and Murai would not have suggested modifying Degner's electrode to result in the claimed low resistivity silicon electrode.

VI. The Examiner Has Established No Motivation to Modify Murai's Non-Showerhead Electrode to Produce the Claimed Showerhead Electrode

Murai discloses a plasma chamber including an upper electrode 2a positioned in the chamber 5. Murai's chamber includes a **single** gas supply pipe 4 located at the sidewall of the chamber 5 to introduce the doping gas horizontally, as depicted in Figure 1 of Murai. (Substitute Appeal Brief at page 25, last two paragraphs). The electrode 2a is **not** a showerhead electrode having a plurality of gas outlets arranged to distribute process gas in a plasma processing chamber, as claimed.

Although Murai's upper electrode 2a is **not** a showerhead electrode and process gas is **not** introduced into the chamber via the upper electrode 2a, but is introduced via the single gas supply pipe 4 located in the chamber sidewall, the Examiner contends that "Degner et al. does not change the principle of operation of Murai since modifying Murai with Degner et al. would still allow for Murai to be used as **an electrode** consistent with the teachings of Murai" (emphasis added). (Examiner's Answer at page 23, lines 13-16). This position is improper because the claimed subject matter is directed to a showerhead electrode and the applied references fail to suggest the **desirability** of modifying Murai to result in the claimed subject matter. See M.P.E.P. § 2143.01(I). The Examiner has provided no reason why one skilled in the art would replace Murai's non-showerhead upper electrode 2a

with a more-expensive showerhead electrode that would **not** even function in the chamber 5 as a showerhead electrode because the doping gas would still not be introduced into the chamber via such alleged showerhead electrode, but would still be introduced into the chamber 5 via the gas supply pipe 4 located at the sidewall of the chamber 5. As such, there would have been no reason for one skilled in the art to modify Murai's upper electrode 2a to include **any** gas outlets, much less a **plurality** of gas outlets arranged to distribute process gas in the plasma reaction chamber, as claimed.

Also, as discussed above, assuming that Murai is considered by the Examiner to be the "closest prior art," then the result of the claimed subject matter should properly be compared to Murai. However, Murai does not disclose the claimed electrode thickness of about 0.25 inch or higher. Accordingly, unexpected advantages that result from the claimed thickness, such as reduced center-to-edge temperature gradient, increased lifetime and reduced byproduct deposition behind the electrode, are sufficient to rebut the alleged *prima facie* obviousness based on the combinations of Murai and Degner and Murai, Degner and Saito.

For at least the above reasons, the rejection of Claims 1, 4-10, 30, 38, 39 and 41 under 35 U.S.C. § 103(a) over Murai in view of Degner, and the rejection of Claims 3, 21, 25, 27, 33-37 and 40 under 35 U.S.C. § 103(a) over Murai in view of Degner and Saito, should be reversed.

VII. The Examiner Has Established No Motivation to Modify Saito's Thin Electrode to Produce the Claimed Showerhead Electrode

Claims 1, 3-10, 21, 25, 27, 30, 31 and 33-41 stand rejected under 35 U.S.C. § 103(a) over Saito in view of Degner. Saito discloses a silicon sheet having a thickness of only 5 mm **prior to etching**, i.e., less than 0.2 inch (column 3, lines 13-20), which is significantly thinner than the claimed minimum electrode thickness of about 0.25 inch or greater.

Degner discloses an electrode 12 having a thickness from 0.1 cm to 2 cm (0.04 inch to 0.79 inch). However, Degner discloses at column 4, lines 25-29, that it is desirable to **minimize** the thickness of the electrode for expensive materials. Single crystal silicon is an expensive material. Degner also discloses that electrodes as thin as 0.1 cm (0.12 inch) can be used. The Examiner has arbitrarily selected a particular portion of Degner's thickness range, which is much higher than Saito's disclosed thickness.

Also, as discussed above, assuming that Saito is considered by the Examiner to be the "closest prior art," then the result of the claimed subject matter should properly be compared to Sato. But Sato does not disclose the claimed electrode thickness of about 0.25 inch or higher. Accordingly, unexpected advantages that result from the claimed thickness, such as a reduced center-to-edge temperature gradient, increased lifetime and reduced byproduct deposition behind the electrode, are sufficient to rebut the alleged *prima facie* obviousness based on the combination of Saito and Degner.

Accordingly, the rejection of Claims 1, 3-10, 21, 25, 27, 30, 31 and 33-41 under 35 U.S.C. § 103(a) over Saito in view of Degner should be reversed.

VIII. Conclusion

Therefore, reversal of each of the outstanding rejections is earnestly solicited. No fee is believed to be due for this reply. However, the Commissioner is hereby authorized to charge any fees that may be required by this paper, and to credit any overpayment, to Deposit Account No. 02-4800.

Respectfully submitted,

BUCHANAN INGERSOLL & ROONEY PC

Date: July 31, 2006

By: Edward A. Brown

Edward A. Brown
Registration No. 35,033

P.O. Box 1404
Alexandria, Virginia 22313-1404
(703) 836-6620

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Periodic Table of Elements

Element Silicon - Si

Comprehensive data on the chemical element Silicon is provided on this page; including scores of properties, element names in many languages, most known nuclides of Silicon. For many elements information on common compounds of is now provided as well. In addition technical terms are linked to their definitions and the menu contains links to related articles that are a great aid in one studies. Using the "Periodic Table of Elements Quick Navigation" graphic at the bottom of the sidebar menu, one can quickly jump from chemical element to chemical element.

Silicon Menu

Overview of Silicon

- Atomic Number: 14
- Group: 14
- Period: 3
- Series: Metalloids (Nonmetal)

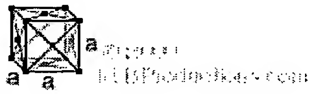
Silicon's Name in Other Languages

- **Latin:** Silicium
- **Czech:** Křemík
- **Croatian:** Silicij
- **French:** Silicium
- **German:** Silizium - r
- **Italian:** Silicio
- **Norwegian:** Silisium
- **Portuguese:** Silício
- **Russian:** Кремний
- **Spanish:** Silicio
- **Swedish:** Kisel

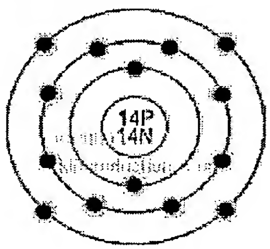
Atomic Structure of Silicon

- **Atomic Radius:** 1.46Å
- **Atomic Volume:** 12.1cm³/mol
- **Covalent Radius:** 1.11Å

- **Cross Section**: 160barns ±20
- **Crystal Structure**: Cubic face centered



- **Electron Configuration:**
  $1s^2\ 2s^2p^6\ 3s^2p^2$
- **Electrons per Energy Level**: 2,8,4
  Shell Model



- **Ionic Radius**: 0.4Å
- **Filling Orbital**: $3p^2$
- **Number of Electrons (with no charge)**: 14
- **Number of Neutrons (most common/stable nuclide)**: 14
- **Number of Protons**: 14
- **Oxidation States**: 4
- **valence Electrons**: $3s^2p^2$
  Electron Dot Model

Chemical Properties of Silicon

- **Electrochemical Equivalent**: 0.26197g/amp-hr
- **Electron Work Function**: 4.52eV
- **Electronegativity (Pauling)**: 1.9
- **Heat of Fusion**: 50.55kJ/mol
- **Incompatiblities:**
  Chlorine, fluorine, oxidizers, calcium, cesium carbide, alkaline carbonates
- **Ionization Potential**
  First: 8.151
  Second: 16.345
  Third: 33.492
- **valence Electron Potential (-eV)**: 144

Physical Properties of Silicon

Note: temperature and pressure sensitive calculations are based on normal temperature and pressure (20°C @ 1atm).

- **Atomic Mass Average**: 28.0855
- **Boiling Point**: 2628K 2355°C 4271°F
- **Coefficient of Linear Thermal Expansion:**
  0.0000042cm/cm/°C (0°C)
- **Conductivity**
  Electrical: $2.52E^{-12}$ 10^6/cm Ω
  Thermal: 1.48 W/cmK
- **Density**: 2.33g/cc @ 300K

- **Description:**
  Hard dark gray non-metal.
- **Elastic Modulus:**
  Bulk: 100/GPa
  Youngs: 47/GPa
- **Enthalpy of Atomization:** 439.3 kJ/mole @ 25°C
- **Enthalpy of Fusion:** 46.44 kJ/mole
- **Enthalpy of Vaporization:** 439 kJ/mole
- **Flammablity Class:** Combusrible Solid in powder form
- **Freezing Point:** *see melting point*
- **Hardness Scale**
  Mohs: 6.5
- **Heat of Vaporization:** 384.22kJ/mol
- **Melting Point:** 1683K 1410°C 2570°F
- **Molar Volume:** 12.05 cm^3/mole
- **Optical Reflectivity:** 28%
- **Pysical State (at 20°C & 1atm):** Solid
- **Specific Heat:** 0.71J/gK
- **Vapor Pressure** = 4.77@1410°C

Regulatory / Health
- **CAS Number**: 7440-21-3 amorphous powder
- **UN/NA ID (ERG Guide Number)**: 1346 (170) amorphous powder
- **RTECS:** VW0400000
- **OSHA Permissible Exposure Limit (PEL)**
  TWA: 15 mg/m^3 total particulate
  5 mg/m^3 respirable particulate
- **OSHA PEL Vacated 1989**
  TWA: 10 mg/m^3 total particulate
  5 mg/m^3 respirable particulate
- **NIOSH Recommended Exposure Limit (REL)**
  TWA: 10 mg/m^3 total particulate
  5 mg/m^3 respirable particulate
- **Routes of Exposure:** Inhalation; Ingestion; Skin and/or eye contact
- **Target Organs:** Eyes, skin, respiratory system

Who / Where / When / How
- **Discoverer:** Jöns Berzelius
- **Discovery Location:** Sweden
- **Discovery Year:** 1823
- **Name Origin:**
  Latin: Latin: silex (flint).
- **Sources:**
  Silicon is the second most abundant element and comprises 25% of the earth's crust. Makes up major portion of clay, granite, quartz (SiO_2), and sand.
- **Uses:**
  Used in glass as silicon dioxide (SiO_2). It is used as a semiconductor to make microchips for electronics (like your computer). Silicon is also used in solar cells, tools, cement, grease and oils.
- **Additional Notes:**
  Silicon carbide (SiC) is one of the hardest substances known.

Continued below

Silicon Menu

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